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LISTS OF SPECIES

Bees (Hymenoptera: Apoidea: Apidae s.l.) captured with Malaise and pan traps along an altitudinal gradient in the Parque Estadual da Serra do Mar, Ubatuba, São Paulo, Brazil

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ABSTRACT: A list of bee species surveyed along an altitudinal gradient in Ubatuba, Brazil using Malaise and pan traps is presented. A total of 289 individuals representing 57 species, 33 genera, and 5 subfamilies were collected. Most individuals and species were collected at around 600 m altitude, and almost all species were collected with Malaise traps. Detrended Correspondence Analysis revealed a correlation between the occurrence of stingless bees and the altitude, confirming the usefulness of stingless-bee communities to reveal gradient patterns.

INTRODUCTION

The Atlantic Forest is one of the most biologically rich and endangered natural environments in the world (Myers *et al*. 2000). This situation has encouraged the study and conservation of this biome; however, the bee fauna, the most important pollinator group, remains virtually unknown. Certain aspects of bee distributional patterns, such as latitudinal and altitudinal gradients, are poorly known (Gonçalves and Brandão 2008), primarily because of the difficulty of sampling forested areas. Structured bee inventories are relatively common for areas with open vegetation (Pinheiro-Machado 2002). The standard sampling protocol consists of a year of sampling in a defined area, using entomological nets to capture bees that are visiting flowers or flying (Sakagami *et al*. 1967). Net sampling is considered the best method to assess the bee fauna, but it demands a huge collecting effort. Therefore, alternative methodologies such as pan traps could be useful to evaluate the bee fauna in a certain area (Roulston *et al*. 2007). Gonçalves and Brandão (2008) reported the bees sampled during the project "Biodiversity of Hymenoptera and Isoptera: richness and diversity along a latitudinal gradient in the Atlantic Forest – the humid eastern forest of Brazil", within the Biota-Fapesp Program. The goal of the main project was to assess the latitudinal gradient, and the sampling protocol included pan and malaise traps and vegetation netting. The results were very positive: the sampled bees were representative of the Atlantic Forest biome, and ordination analysis with the stingless bees (Meliponina) proved to be appropriate to evaluate the latitudinal-gradient effect.

The present contribution lists and comments on the bee species sampled with malaise and pan traps along an altitudinal gradient in the Parque Estadual da Serra do Mar, Ubatuba. This project supplemented the knowledge of this area gained by previous sampling within the Biota-Fapesp project, and of the Atlantic Forest bee fauna.

MATERIAL AND METHODS

The altitudinal gradient extended along the Cuzcuzeiro hill, reaching 1,270 m a.s.l. This hill is located in the Núcleo Picinguaba do Parque Estadual da Serra do Mar (NPIC; Picinguaba Unit of the Serra do Mar State Park), Ubatuba, São Paulo, Brazil, between the coordinates 23°17'56.4" S 44°47'13.2" W (1000 m a.s.l.) and 23°20'24" S 44°49'26.4" W (50 m a.s.l.). The NPIC is an Atlantic Forest conservation area of 47,000 ha, located in the extreme northeast of the state of São Paulo. The NPIC is surrounded by other conservation areas, and includes both coastal-plain areas and hills that range above 1000 m altitude (IBGE 1974; Hirota and Ponzoni 2010).

The sampling protocols were modified from the project "Biodiversity of Hymenoptera and Isoptera: richness and diversity along a latitudinal gradient in the Atlantic Forest – the humid eastern forest of Brazil", within the Biota-Fapesp Program. Two sampling techniques, malaise traps (model of Townes 1972) and pan traps were adopted, with traps installed at the 50, 200, 400, 600, 800 and 1,000 m levels. At each level, 5 black malaise traps were installed 100 m apart from each other, and 12 yellow pan traps of 22 mm diameter were installed in groups of 5 traps spaced 50 m from each other. The sampling period was in the rainy seasons of 2006 and 2007: monthly collections from January 15 to March 19 in 2006, and from January 17 to March 2 in 2007. These techniques were defined to optimize the collection of vespoid wasps; the bees were a secondary product of the sampling protocol.

All material was stored in plastic tubes with 70%

ethanol and transported to the Hymenoptera laboratory of the Museu de Zoologia of the Universidade de São Paulo (MZUSP). The bees were removed from the tubes, pinned, labeled, deposited and compared by RBG with material already deposited in the MZUSP.

A Detrended Correspondence Analysis (DCA) using a matrix of abundance of Meliponina species and each altitudinal level was performed with Past (Hammer 2001). Only stingless bees were included in this analysis, because as perennial insects, they are not affected by seasonality and their populations are relatively larger than those of other bees.

Results and Discussion

Table 1 shows the species and numbers of individuals by each altitudinal level, as well as the species sampled in Ubatuba by Biota project (Gonçalves and Brandão 2008). The present survey captured 289 individuals representing 57 species, 33 genera, and 5 subfamilies. The most species-rich subfamilies were Apinae with 32 species, followed by Halictinae with 10 species; very few species of other subfamilies were collected. The most species-rich and abundant tribe was Apini, especially the stingless bees. The commonest bee was *Trigona* aff. *fulviventris* with 90 specimens, followed by *Schwarziana quadripunctata* (39) and *Plebeia remota* (20). A total of 16 species were shared with the previous sampling in this area, which used similar methodology (Gonçalves and Brandão 2008); five of the species collected in the previous study did not appear in the present survey but 36 species were sampled only in this survey (Table 1). These differences were expected since the sampled period of first study was only one month (January), and the present study sampled three months (January to March) in two consecutive years.

Almost all bees were captured exclusively with malaise traps. Only two species collected with malaise traps were also collected with pan traps, *Apis mellifera,* 2 individuals at 600 m, and *Schwarziana quadripunctata,* 37 individuals at 800 m a.s.l.

With respect to the richness and abundance estimated for each altitudinal level, the sample from 600 m was the richest and most abundant, whereas the sample from 1000 m was the poorest in both taxa and numbers of individuals. The sample from 50 m was also quantitatively important. For the bee fauna as a whole, the ordering of samples based on richness was 600 > 50 > 400 > 800 > 200 > 1000 m, and based on general abundance was 600 > 50 > 800 > 200 > 400 > 1000 m.

The DCA scatterplot for the presence of Meliponina species and altitude is presented in Figure 1 (eigenvalues: DC1 = 0.55, DC2 = 0.12). The analysis revealed an ordering of the altitudinal levels expressed on DC1. Most species were grouped with the high points: *P. subnuda* (numbering 11), *L. tropica* (7), *M. quadrifasciata* (9) and *S. quadripunctata* (14). The sample for 1,000 m was plotted relatively far from the other sample points on DC2, possibly because of the small number of species (three).

Compared with other inventories (Gonçalves and Melo 2005; Wilms, unpublished data), a very small number of species was collected in this survey. This small number results from the relatively low efficiency of sampling bees with traps compared to active capture using entomological nets (Laroca and Orth 2002). In spite of this low efficiency, the present inventory succeeded in sampling bees that are commonly associated with the Atlantic Forest. The comparative richness of stingless and orchid bees combined with species including *Ariphanarthra palpalis*, *Corynurella mourei*, *Dithygater seabrai* and *Ptiloglossa lucernarum* may be associated with the forested environment sampled. Interestingly, a relatively large number of species of Osirini (six) was collected. This tribe is composed only by kleptoparasites, which are underestimated in traditional inventory studies because of their rarity (Laroca and Orth 2002). Members of Osirini are known as cleptoparasites of species of Tapinotaspidini (Michener 2007), but only four species of this tribe were collected in the present survey.

Krug and Alves-dos-Santos (2008) found pan traps to be useful in sampling in an Araucaria forest. Other studies have demonstrated the efficiency of this sampling methodology in both natural and agricultural areas (see Gollan *et al*. 2011; Roulston *et al*. 2007; Tuell and Isaacs 2009 for examples of recent use). Our results concord with those of Gonçalves and Brandão (2008), who reported a low efficiency of this method for the Atlantic Forest. The efficiency of pan traps is not well studied, and may be closely dependent on the local vegetation type or on abiotic factors such as water availability. In addition, pan traps can be positioned close to flowers in open areas of vegetation, possibly increasing sampling rates.

The altitudinal gradient could be evaluated using the DCA of Meliponina species versus altitude (Figure 1). This kind of data ordination proved to be robust for tracing gradients of stingless bees versus area. An earlier study found a relationship between the occurrence of Meliponina and a latitudinal gradient in the Atlantic Forest (Gonçalves and Brandão 2008). Analysis of the bees as a whole was not possible here because of the inefficiency of the sampling methodology. In optimal sampling conditions, with the use of entomological netting, a DCA using bee genera versus areas could identify a pattern of open areas (Gonçalves et al. 2009).

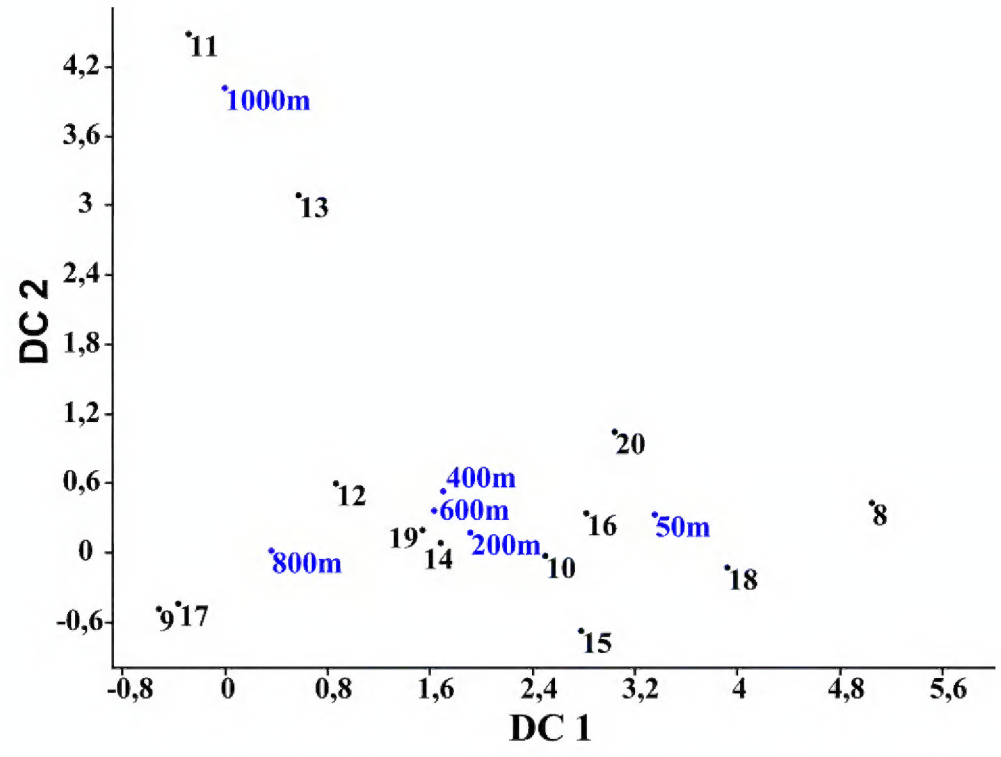

Figure 1. Scatterplot of Detrended Correspondence Analysis based on abundance of Meliponina species and altitudinal levels in Parque Estadual da Serra do Mar, Núcleo Picinguaba, Ubatuba, São Paulo, Brazil. Black numbers correspond to species as listed in Table 1, and blue numbers refer to altitude.

Table 1. Number of bees in each elevation sample collected on Parque Estadual da Serra do Mar - Núcleo Picinguaba, Ubatuba, São Paulo, Brazil, with species previously sampled for the same area (Biota: Gonçalves and Brandão 2008).* two individuals sampled with pan traps, ** all individuals sampled with pan traps.

N	BEE	50M	200M	400M	600M	800M	1000M	TOTAL	BIOTA
	Andreninae								
	Protandrenini								
1	*Rhophitulus* sp.1	0	1	0	0	0	0	1	
	Apinae								
	Apini								
2	*Apis mellifera* Linnaeus, 1758	0	0	0	3*	2	0	5	X
3	*Bombus* (*Fervidobombus*) *brasiliensis* Lepeletier, 1836	0	0	0	4	0	0	4	X
4	*Bombus* (*Fervidobombus*) *morio* (Swederus, 1787)	0	0	0	0	0	0	0	X
5	*Euglossa* (*Euglossella*) *mandibularis* Friese, 1899	0	0	0	1	0	0	1	
6	*Euglossa* (*Glossura*) *iopoecila* Dressler, 1972	1	0	0	0	0	0	1	
7	*Euglossa* (*Glossurella*) *stellfeldi* Moure, 1947	1	0	0	0	0	0	1	
8	*Lestremelitta ehrhardti* (Friese, 1931)	1	0	0	0	0	0	1	X
9	*Lestremelitta tropica* Marchi and Melo, 2006	0	0	0	0	1	0	1	
10	*Melipona* (*Eomelipona*) *marginata* Moure, 1971	1	0	0	0	1	0	2	
11	*Melipona* (*Eomelipona*) *quadrifasciata* Lepeletier, 1836	0	0	1	0	2	2	5	X
12	*Melipona* (*Michmelia*) *rufiventris* Lepeletier, 1836	0	0	1	2	2	0	5	X
13	*Paratrigona subnuda* Moure, 1947	0	0	0	2	1	1	4	
14	*Partamona helleri* (Friese, 1900)	0	1	0	5	1	0	7	X
15	*Plebeia phrynostoma* Moure, 2004	0	2	0	0	0	0	2	X
16	*Plebeia remota* (Holmberg, 1903)	2	9	3	6	0	0	20	X
17	*Schwarziana quadripunctata* (Lepeletier, 1836)	0	0	0	2	37**	0	39	
18	*Tetragonisca angustula* (Latreille, 1811)	1	1	0	0	0	0	2	
19	*Trigona aff. fulviventris* Guérin, 1835	0	31	12	26	21	0	90	X
20	*Trigona spinipes* (Fabricius, 1793)	1	0	1	2	0	0	4	X
	Eucerini								
21	*Dithygater seabrai* (Moure and Michener, 1955)	0	1	0	2	0	0	3	
	Osirini								
22	*Osiris* sp.1	3	1	0	0	0	0	4	X
23	*Osiris* sp.2	0	1	0	0	0	0	1	
24	*Osiris* sp.3	1	0	1	1	0	0	3	
25	*Protosiris mcginley* (Shanks, 1986)	0	0	1	7	0	0	8	
26	*Protosiris* sp.1	1	0	0	1	0	0	2	
27	*Protosiris* sp.2	0	0	1	0	0	0	1	
	Tapinotaspidini								
28	*Paratetrapedia fervida* (Smith, 1879)	1	1	0	0	1	1	4	
29	*Trigonopedia ferruginea* (Friese, 1899)	0	0	0	5	1	0	6	
30	*Trigonopedia* sp.1	0	0	0	0	1	0	1	
	Tetrapediini								
31	*Tetrapedia* sp.1	0	0	0	1	0	0	1	
	Xylocopini								
32	*Ceratina* (*Ceratinula*) sp.1	0	0	0	4	0	0	4	X
33	*Ceratina* (*Rhysoceratina*) sp.1	4	0	0	0	0	0	4	
	Colletinae								
	Colletini								
34	*Colletes ornatus* Schrottky, 1902	0	1	0	0	0	0	1	
35	*Colletes rugicollis* Friese, 1900	0	0	0	0	0	0	0	X
	Diphaglossini								
36	*Ptiloglossa lucernarum* Cockerell, 1923	0	1	0	0	0	0	1	
	Halictinae								
	Augochlorini								
37	*Ariphanarthra palpalis* Moure, 1951	0	0	0	1	0	0	1	
38	*Augochlorella urania* (Smith, 1853)	0	0	0	0	0	0	0	X
39	*Augochloropsis* sp.1	1	0	3	0	0	0	4	
40	*Augochloropsis* sp.2	1	0	0	0	0	0	1	

Table 1. ***Continued.***

N	BEE	50M	200M	400M	600M	800M	1000M	TOTAL	BIOTA
41	*Corynurella mourei* Eickwort, 1969	1	0	0	0	1	0	2	X
42	*Megommation insigne* (Smith, 1853)	0	1	0	0	0	0	1	
43	*Neocorynura aenigma* (Gribodo, 1894)	0	0	0	2	0	0	2	
44	*Neocorynura* sp.1	0	0	0	0	1	0	1	
45	*Neocorynura* sp.2	0	0	0	0	0	0	0	X
46	*Paroxystoglossa* sp.1	3	0	0	0	0	0	3	
47	*Paroxystoglossa* sp.2	7	0	0	0	0	0	7	
48	*Temnosoma* sp.1	3	1	6	1	0	0	11	
49	*Temnosoma* sp.2	0	0	0	0	0	0	0	X
	Halictini								
50	*Dialictus* sp.1	0	0	0	2	0	0	2	X
51	*Dialictus* sp.2	1	0	0	0	0	0	1	X
52	*Dialictus* sp.3	0	0	0	1	0	0	1	
53	*Dialictus* sp.4	2	0	0	0	0	0	2	
54	*Habralictus flavopictus* Moure, 1941	0	1	0	1	1	0	3	
55	*Microsphecodes russeiclypeatus* (Sakagami and Moure, 1962)	0	0	1	0	0	0	1	
56	*Microsphecodes* sp.1	1	3	0	0	0	0	4	
	Megachilinae								
	Megachilini								
57	*Coelioxys* (*Cyrtocoelioxys*) sp.1	2	0	0	1	0	0	3	X
	Total	40	56	31	83	74	4	289	

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